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DTC PROJECT NO. 8-CO-160-UXO-021
REPORT NO. ATC-9359

STANDARDIZED

UXO TECHNOLOGY DEMONSTRATION SITE

BLIND GRID SCORING RECORD NO. 805

SITE LOCATION:
U.S. ARMY YUMA PROVING GROUND

DEMONSTRATOR:
U.S. GEOLOGICAL SURVEY (USGS)
BOX 25046, FEDERAL CENTER, M.S. 964
DENVER, CO 80225-0046

TECHNOLOGY TYPE/PLATFORM:
EM ALL TEM/TOWED ARRAY

PREPARED BY:
U.S. ARMY ABERDEEN TEST CENTER
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MARCH 2007

Prepared for:
U.S. ARMY ENVIRONMENTAL COMMAND
ABERDEEN PROVING GROUND, MD 21010-5401

U.S. ARMY DEVELOPMENTAL TEST COMMAND
ABERDEEN PROVING GROUND, MD 21005-5055

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14. ABSTRACT

This scoring record documents the efforts of the U.S. Geological Survey to detect and discriminate inert unexploded ordnance (UXO) utilizing the YPG Standardized UXO Technology Demonstration Site Blind Grid. This Scoring Record was coordinated by Michael Karwatka and the Standardized UXO Technology Demonstration Site Scoring Committee. Organizations on the committee include the U.S. Army Corps of Engineers, the Environmental Security Technology Certification Program, the Strategic Environmental Research and Development Program, the Institute for Defense Analysis, the U.S. Army Environmental Command, and the U.S. Army Aberdeen Test Center.

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SECTION 1. GENERAL INFORMATION

1.1 BACKGROUND

Technologies under development for the detection and discrimination of munitions and explosives of concern (MEC) - i.e. unexploded ordnance (UXO) and discarded military munitions (DMM) require testing so that their performance can be characterized. To that end, Standardized Test Sites have been developed at Aberdeen Proving Ground (APG), Maryland and U.S. Army Yuma Proving Ground (YPG), Arizona. These test sites provide a diversity of geology, climate, terrain, and weather as well as diversity in ordnance and clutter. Testing at these sites is independently administered and analyzed by the government for the purposes of characterizing technologies, tracking performance with system development, comparing performance of different systems, and comparing performance in different environments.

The Standardized UXO Technology Demonstration Site Program is a multi-agency program spearheaded by the U.S. Army Environmental Command (USAEC). The U.S. Army Aberdeen Test Center (ATC) and the U.S. Army Corps of Engineers Engineering Research and Development Center (ERDC) provide programmatic support. The program is being funded and supported by the Environmental Security Technology Certification Program (ESTCP), the Strategic Environmental Research and Development Program (SERDP) and the Army Environmental Quality Technology Program (EQT).

1.2 SCORING OBJECTIVES

The objective in the Standardized UXO Technology Demonstration Site Program is to evaluate the detection and discrimination capabilities of a given technology under various field and soil conditions. Inert munitions and clutter items are positioned in various orientations and depths in the ground.

The evaluation objectives are as follows:

a. To determine detection and discrimination effectiveness under realistic scenarios that vary targets, geology, clutter, topography, and vegetation.

b. To determine cost, time, and manpower requirements to operate the technology.

c. To determine demonstrator’s ability to analyze survey data in a timely manner and provide prioritized “Target Lists” with associated confidence levels.

d. To provide independent site management to enable the collection of high quality, ground-truth, geo-referenced data for post-demonstration analysis.

1.2.1 <u>Scoring Methodology</u>

a. The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the RESPONSE STAGE and DISCRIMINATION STAGE. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver-operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of false positive (P_{fp}), and those that do not correspond to any known item, termed background alarms.

b. The RESPONSE STAGE scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. For the blind grid RESPONSE STAGE, the demonstrator provides the scoring committee with a target response from each and every grid square along with a noise level below which target responses are deemed insufficient to warrant further investigation. This list is generated with minimal processing and, since a value is provided for every grid square, will include signals both above and below the system noise level.

c. The DISCRIMINATION STAGE evaluates the demonstrator's ability to correctly identify ordnance as such and to reject clutter. For the blind grid DISCRIMINATION STAGE, the demonstrator provides the scoring committee with the output of the algorithms applied in the discrimination-stage processing for each grid square. The values in this list are prioritized based on the demonstrator's determination that a grid square is likely to contain ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For digital signal processing, priority ranking is based on algorithm output. For other discrimination approaches, priority ranking is based on human (subjective) judgment. The demonstrator also specifies the threshold in the prioritized ranking that provides optimum performance, (i.e. that is expected to retain all detected ordnance and rejects the maximum amount of clutter).

d. The demonstrator is also scored on EFFICIENCY and REJECTION RATIO, which measures the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from non-ordnance items. EFFICIENCY measures the fraction of detected ordnance retained after discrimination, while the REJECTION RATIO measures the fraction of false alarms rejected. Both measures are defined relative to performance at the demonstrator-supplied level below which all responses are considered noise, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

e. All scoring factors are generated utilizing the Standardized UXO Probability and Plot Program, version 3.1.1.

1.2.2 <u>Scoring Factors</u>

Factors to be measured and evaluated as part of this demonstration include:

a. Response Stage ROC Curves:

(1) Probability of Detection (P_d^{res}).

(2) Probability of False Positive (P_{fp}^{res}).

(3) Background Alarm Rate (BAR^{res}) or Probability of Background Alarm (P_{BA}^{res}).

b. Discrimination Stage ROC Curves:

(1) Probability of Detection (P_d^{disc}).

(2) Probability of False Positive (P_{fp}^{disc}).

(3) Background Alarm Rate (BAR^{disc}) or Probability of Background Alarm (P_{BA}^{disc}).

c. Metrics:

(1) Efficiency (E).

(2) False Positive Rejection Rate (R_{fp}).

(3) Background Alarm Rejection Rate (R_{BA}).

d. Other:

(1) Probability of Detection by Size and Depth.

(2) Classification by type (i.e., 20-mm, 40-mm, 105-mm, etc.).

(3) Location accuracy.

(4) Equipment setup, calibration time and corresponding man-hour requirements.

(5) Survey time and corresponding man-hour requirements.

(6) Reacquisition/resurvey time and man-hour requirements (if any).

(7) Downtime due to system malfunctions and maintenance requirements.

1.3 STANDARD AND NONSTANDARD INERT ORDNANCE TARGETS

The standard and nonstandard ordnance items emplaced in the test areas are listed in Table 1. Standardized targets are members of a set of specific ordnance items that have identical properties to all other items in the set (caliber, configuration, size, weight, aspect ratio, material, filler, magnetic remanence, and nomenclature). Nonstandard targets are ordnance items having properties that differ from those in the set of standardized targets.

TABLE 1. INERT ORDNANCE TARGETS

Standard Type	Nonstandard (NS)
20-mm Projectile M55	20-mm Projectile M55
	20-mm Projectile M97
40-mm Grenades M385	40-mm Grenades M385
40-mm Projectile MKII Bodies	40-mm Projectile M813
BDU-28 Submunition	
BLU-26 Submunition	
M42 Submunition	
57-mm Projectile APC M86	
60-mm Mortar M49A3	60-mm Mortar (JPG)
	60-mm Mortar M49
2.75-inch Rocket M230	2.75-inch Rocket M230
	2.75-inch Rocket XM229
MK 118 ROCKEYE	
81-mm Mortar M374	81-mm Mortar (JPG)
	81-mm Mortar M374
105-mm HEAT Rounds M456	
105-mm Projectile M60	105-mm Projectile M60
155-mm Projectile M483A1	155-mm Projectile M483A
	500-lb Bomb
	M75 Submunition

JPG = Jefferson Proving Ground.
HEAT = high-explosive antitank.

SECTION 2. DEMONSTRATION

2.1 DEMONSTRATOR INFORMATION

2.1.1 Demonstrator Point of Contact (POC) and Address

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2.1.2 System Description (provided by demonstrator)

a. The ALL TEM system (fig. 1) development has the primary aim of eliminating shortcomings of very early time electromagnetic (VETEM) and the high frequency sounder (HFS) with respect to UXO detection, location, and identification. Primary differences include the following:

(1) ALL TEM can record to late times, which VETEM could not do. The advantage of this feature is expected to be suppression of geologic response relative to UXO response.

(2) The triangle current excitation waveform provides immediate visual separation between ferrous and nonferrous metal objects.

(3) We can excite and detect three-component fields by using multiple transmitter (TX) and receiver (RX) coils.

b. The Tensor Magnetic Gradiometer System (TMGS) has been reconfigured to improve its performance compared with the original system that was tested at YPG in 2003.

(1) The system uses four three-axis fluxgate magnetometers.

(2) This system has theoretical advantages in terms of rejection of distant noise sources and in target identification.

Figure 1. Demonstrator's system, EM ALL TEM/towed array.

2.1.3 <u>Data Processing Description (provided by demonstrator)</u>

The ALL TEM is controlled by a LabVIEW data acquisition program written by the USGS. This program allows the operator to select operational parameters, such as gain base frequency, record length, filters, and number of waveforms averaged. In addition, the program provides real-time data visualization. Headers in the data contain the operating parameters. Navigation data from the real-time kinematic differential global positioning system (GPS) are a part of the data stream. The USGS plans to acquire data with a spatial data density along a track of about 25 cm and with line spacing of 50 cm and the ALL TEM moving at anticipated speeds of 50 to 100 cm/s. The data format for the ALL TEM is an American Standard Code for Information Interchange (ASCII) header containing system setting information, time stamp, and GPS data followed by variable-length 24-bit binary data from each of several receiving loops. Records are typically written at rates of five per second. For each data format, the demonstrator will provide an annotated example for use as a "key" to import and parse the data, as well as a description of file-naming nomenclature. The comparison EM61 MKII system will be operated with the GPS and the same line spacing as the ALL TEM.

The TMGS raw data files consist of an ASCII header with system settings followed by the data in binary format. The GPS positions, EDA FM100B three-axis fluxgate base station data, are recorded separately on a portable personal computer (PC) in ASCII format and time-tagged. The Geometrics G-858G cesium vapor magnetic gradiometer logs data internally. MAGMAP2000 software transfers the data from the G-858G to a PC, where it is exported in ASCII format. A new data acquisition system for the TMGS will be supplied by the demonstrator. It is controlled by LabVIEW, as is the ALL TEM system. Details of the data

format are still under development. The new system is expected to have much tighter time control, synchronized to GPS time.

2.1.4 Data Submission Format

Data were submitted for scoring in accordance with data submission protocols outlined in the Standardized UXO Technology Demonstration Site Handbook. These submitted data are not included in this report in order to protect ground truth information.

2.1.5 Demonstrator Quality Assurance (QA) and Quality Control (QC) (provided by demonstrator)

The ALL TEM system and the TMGS have real-time data displays that instantly show the operator if the transmitting/receiving functions of the system fail. In addition, the demonstrator will find a location with no known targets and repetitively reoccupy that location and record data, including GPS data, to assess and document any drifts that may occur in the instrumentation. The standard operating procedure with all systems is to occupy a designated clean location at least twice each day: prior to and at the completion of regular data acquisition. This usually takes place in the morning and the afternoon, but in case of an extended pause in the middle of the day, an additional reference data set may be acquired. This will also test the accuracy and repeatability of the navigation data. As with all analog and time-based systems, drift will occur mainly as a result of component tolerances and temperature dependencies. This inherent system drift limits the absolute accuracy of the measurements that can be attained. The reference data are used primarily as a metric for overall accuracy. Abnormal drift, as would be caused by battery depletion or component degradation, would trigger a system check and data review. The hardware problem would be corrected and field data acquisition would resume. Any previous data deemed degraded would be reacquired. The USGS also plans to preprocess data overnight or concurrent with data acquisition to visually ensure that there are no serious glitches or “tears” in the data. Any corrupted lines will be repeated. For the TMGS, magnetometer base stations will be set up in a magnetically clean area. The instruments will monitor fluctuations in the earth’s magnetic field, and the data will provide a check on possible sensor baseline shifts in the TMGS. Magnetic storm activity will be monitored on the National Oceanic & Atmospheric Administration (NOAA) space weather web site, www.sec.noaa.gov/SWN. The TMGS tetrahedron will be spin-calibrated to measure deviations from orthogonality of sensor axial components. If possible, the GPS will be referenced to a local geodetic marker.

2.1.6 Additional Records

The following record(s) by this vendor can be accessed via the Internet as MicroSoft Word documents at www.uxotestsites.org.

2.2 YPG SITE INFORMATION

2.2.1 Location

The YPG is located adjacent to the Colorado River in the Sonoran Desert. The UXO Standardized Test Site is located south of Pole Line Road and east of the Countermine Testing and Training Range. The open field range, calibration grid, blind grid, mogul area, and desert extreme area comprise the 350- by 500-meter general test site area. The open field site is the largest of the test sites and measures approximately 200 by 350 meters. To the east of the open field range are the calibration and blind test grids that measure 30 by 40 meters and 40 by 40 meters, respectively. South of the open field is the 135- by 80-meter mogul area consisting of a sequence of man-made depressions. The desert extreme area is located southeast of the open field site and has dimensions of 50 by 100 meters. The desert extreme area, covered with desert-type vegetation, is used to test the performance of different sensor platforms in a more severe desert condition/environment.

2.2.2 Soil Type

Soil samples were collected at the YPG UXO Standardized Test Site by ERDC to characterize the shallow subsurface (< 3 m). Both surface grab samples and continuous soil borings were acquired. The soils were subjected to several laboratory analyses including sieve/hydrometer, water content, magnetic susceptibility, dielectric permittivity, X-ray diffraction, and visual description.

There are two soil complexes present within the site, Riverbend-Carrizo and Cristobal-Gunsight. The Riverbend-Carrizo complex is composed of mixed stream alluvium, whereas the Cristobal-Gunsight complex is derived from fan alluvium. The Cristobal-Gunsight complex covers the majority of the site. Most of the soil samples were classified as either a sandy loam or loamy sand, with most samples containing gravel-sized particles. All samples had a measured water content of less than 7 percent, except for two that contained 11-percent moisture. The majority of soil samples had water content of 1 to 2 percent. Samples containing more than 3 percent were generally deeper than 1 meter.

An X-ray diffraction analysis on four soil samples indicated a basic mineralogy of quartz, calcite, mica, feldspar, magnetite, and some clay. The presence of magnetite imparted a moderate magnetic susceptibility, with volume susceptibilities generally greater than 100 by 10-5 SI.

For more details concerning the soil properties at the YPG test site, go to www.uxotestsites.org on the web to view the entire soils description report.

2.2.3 Test Areas

A description of the test site areas at YPG is presented in Table 2.

TABLE 2. TEST SITE AREAS

Area	Description
Calibration grid	Contains the 15 standard ordnance items buried in six positions at various angles and depths to allow demonstrator equipment calibration.
Blind grid	Contains 400 grid cells in a 0.16-hectare (0.39-acre) site. The center of each grid cell contains ordnance, clutter, or nothing.

SECTION 3. FIELD DATA

3.1 DATE OF FIELD ACTIVITIES (17 through 19 and 22 through 24 May 2006)

3.2 AREAS TESTED/NUMBER OF HOURS

Areas tested and total numbers of hours operated at each site are summarized in Table 3.

TABLE 3. AREAS TESTED AND NUMBER OF HOURS

Area	No. of Hours
Calibration lanes	21.6
Blind grid	26.76

3.3 TEST CONDITIONS

3.3.1 Weather Conditions

A YPG weather station located approximately one mile west of the test site was used to record average temperature and precipitation on a half-hour basis for each day of operation. The temperatures listed in Table 4 represent the average temperature during field operations from 0700 to 1700 hours whereas precipitation data represent a daily total amount of rainfall. Hourly weather logs used to generate this summary are provided in Appendix B.

TABLE 4. TEMPERATURE/PRECIPITATION DATA SUMMARY

Date, 2006	Average Temperature, ^{o}F	Total Daily Precipitation, in.
17 May	97.5	0.00
18 May	95.1	0.00
19 May	95.5	0.00
22 May	73.5	0.03
23 May	82.2	0.00

3.3.2 Field Conditions

The field was dry, and the weather was warm throughout the USGS survey.

3.3.3 Soil Moisture

Three soil probes were placed at various locations within the site to capture soil moisture data: calibration, mogul, open field, and desert extreme areas. Measurements were collected in percent moisture and were taken twice daily (morning and afternoon) from five different soil depths (1 to 6 in., 6 to 12 in., 12 to 24 in., 24 to 36 in., and 36 to 48 in.) from each probe. Soil moisture logs are provided in Appendix C.

3.4 FIELD ACTIVITIES

3.4.1 Setup/Mobilization

These activities included initial mobilization and daily equipment preparation and breakdown. A two-person crew took 5 hours 34 minutes to perform the initial setup and mobilization. There was 1 hour 25 minutes of daily equipment preparation, and the end of the day equipment breakdown lasted 1 hour.

3.4.2 Calibration

The USGS spent a total of 21 hours 40 minutes in the calibration lanes, of which 8 hours 12 minutes was spent collecting data.

3.4.3 Downtime Occasions

Occasions of downtime are grouped into five categories: equipment/data checks or equipment maintenance, equipment failure and repair, weather, demonstration site issues, or breaks/lunch. All downtime is included for the purposes of calculating labor costs (section 5) except for downtime due to demonstration site issues. Demonstration site issues, while noted in the daily log, are considered nonchargeable downtime for the purposes of calculating labor costs and are not discussed. Breaks and lunches are discussed in this section and billed to the total site survey area.

3.4.3.1 Equipment/data checks, maintenance. Equipment data checks and maintenance activities accounted for 6 hours 44 minutes of site usage time. These activities included changing out batteries and routine data checks to ensure the data were being properly recorded/collected. The USGS spent no additional time for breaks and lunches.

3.4.3.2 Equipment failure or repair. Eight hours 6 minutes was needed to resolve equipment failures that occurred while surveying the blind grid. The USGS had to replace the computer system due to slow downloading ability. The USGS replaced the system amplifier and added a ground to the circuit breaker to eliminate extra noise. The USGS also replaced the triangle wave control circuit board to again eliminate any extra noise.

3.4.3.3 Weather. No weather delays occurred during the survey.

3.4.4 Data Collection

The USGS spent a total time of 26 hours 46 minutes in the blind grid area, 9 hours 31 minutes of which was spent collecting data.

3.4.5 Demobilization

The USGS survey crew went on to resurvey the calibration area. Therefore, demobilization did not occur until 24 May 2006. On that day, it took the crew 2 hours 20 minutes to break down and pack up their equipment.

3.5 PROCESSING TIME

The USGS submitted the raw data from the demonstration activities on the last day of the demonstration, as required. The scoring submittal data were provided on 27 July 2006.

3.6 DEMONSTRATOR'S FIELD PERSONNEL

David Wright: Principal Investigator
Theodore Asch: Geophysicist
David Von G. Smith: Principal Investigator
Phillip Brown: Geophysicist
Raymond Hutton: Electronics Engineer

3.7 DEMONSTRATOR'S FIELD SURVEYING METHOD

The USGS surveyed the blind grid in a linear fashion in a north to south and east to west direction.

3.8 SUMMARY OF DAILY LOGS

Daily logs capture all field activities during this demonstration and are provided in Appendix D. Activities pertinent to this specific demonstration are indicated in highlighted text.

SECTION 4. TECHNICAL PERFORMANCE RESULTS

4.1 ROC CURVES USING ALL ORDNANCE CATEGORIES

The probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of false positive is shown in Figure 3. Both probabilities plotted against their respective probability of background alarm are shown in Figure 3. Both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the ground truth.

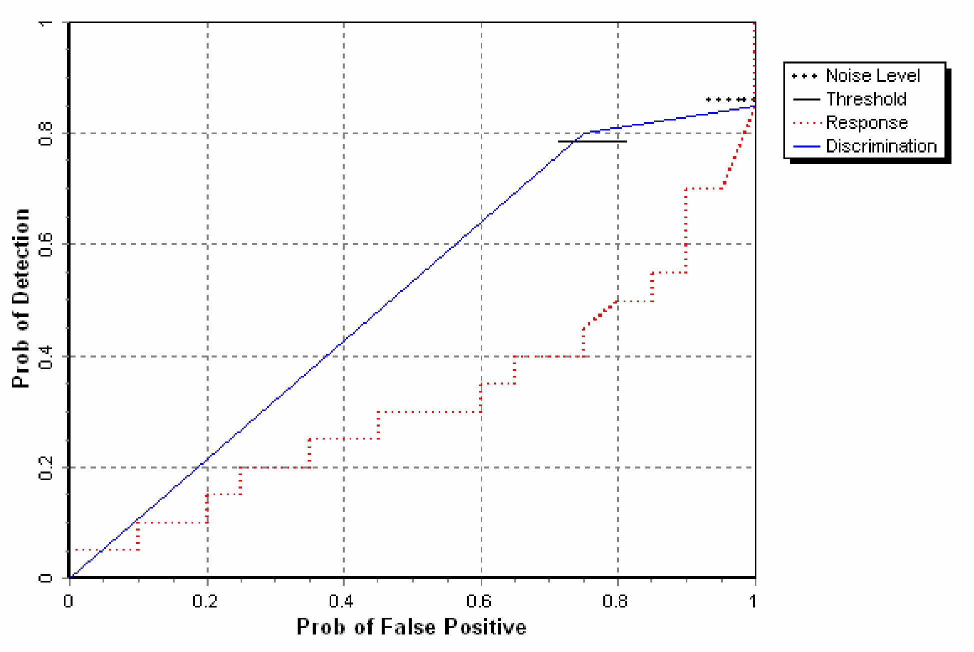

Figure 2. ALL TEM/towed array blind grid probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

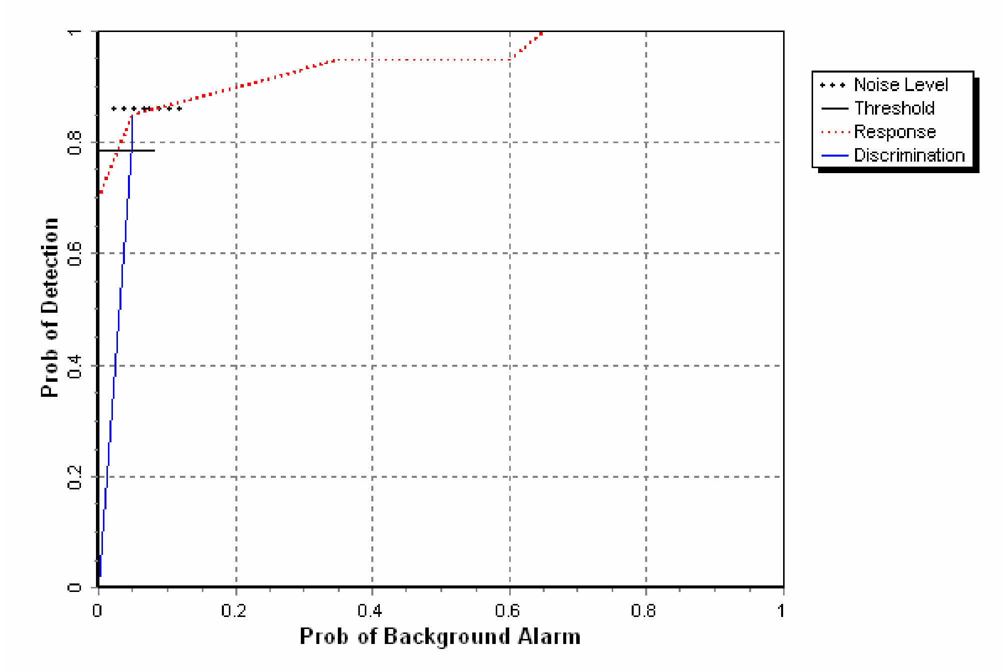

Figure 3. ALL TEM/towed array blind grid probability of detection for response and discrimination stages versus their respective probability of background alarm over all ordnance categories combined.

4.2 ROC CURVES USING ORDNANCE LARGER THAN 20 MM

The probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of false positive when only targets larger than 20 mm are scored is shown in Figure 4. Both probabilities plotted against their respective probability of background alarm are shown in Figure 5. Both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the ground truth.

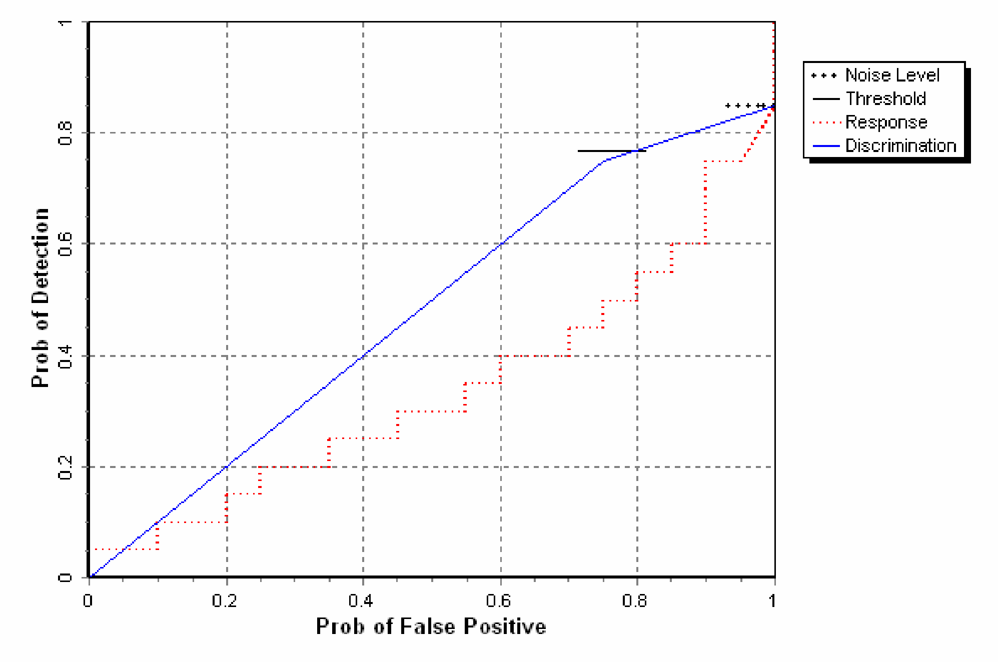

Figure 4. ALL TEM/towed array blind grid probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20 mm.

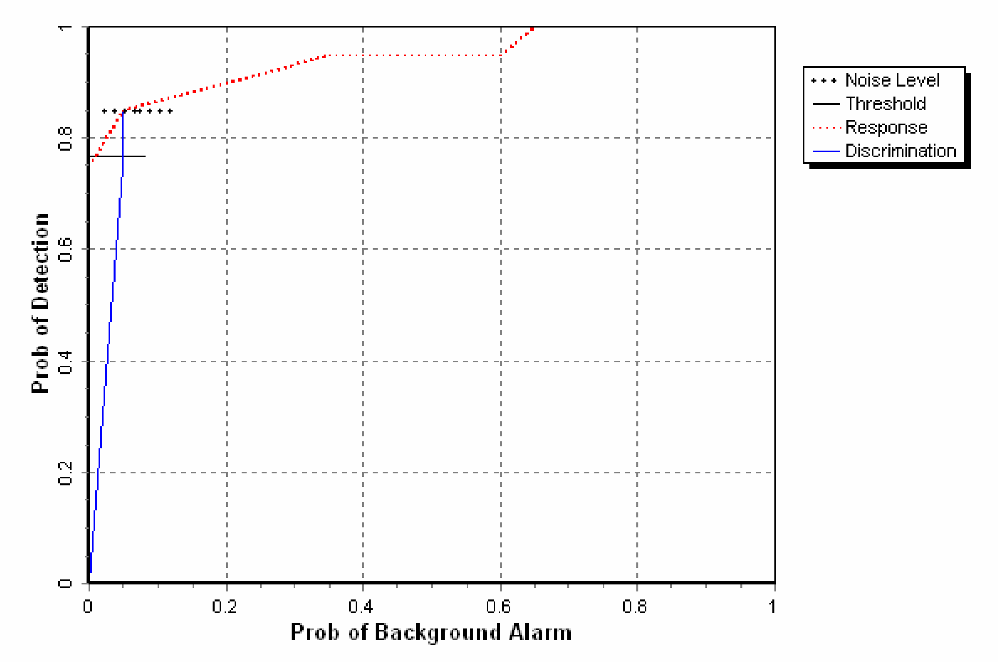

Figure 5. ALL TEM/towed array blind grid probability of detection for response and discrimination stages versus their respective probabilities of background alarm for all ordnance larger than 20 mm.

4.3 PERFORMANCE SUMMARIES

Results for the blind grid test broken out by size, depth, and nonstandard ordnance are presented in Table 5 (for cost results, see section 5). Results by size and depth include both standard and nonstandard ordnance. The results by size show how well the demonstrator did at detecting/discriminating ordnance of a certain caliber range (see app A for size definitions). The results are relative to the number of ordnance items emplaced. Depth is measured from the geometric center of anomalies.

The RESPONSE STAGE results are derived from the list of anomalies above the demonstrator-provided noise level. The results for the DISCRIMINATION STAGE are derived from the demonstrator's recommended threshold for optimizing UXO field cleanup by minimizing false digs and maximizing ordnance recovery. The lower 90-percent confidence limit on probability of detection and P_{fp} was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results in Table 5 have been rounded to protect the ground truth. However, lower confidence limits were calculated using actual results.

TABLE 5. SUMMARY OF BLIND GRID RESULTS FOR THE ALL TEM

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	≥ 1
RESPONSE STAGE									
P_d	0.85	0.85	0.85	0.85	0.80	1.00	0.95	0.85	0.45
P_d Low 90% Conf	0.80	0.78	0.74	0.76	0.63	0.85	0.85	0.73	0.17
P_d Upper 90% Conf	0.91	0.92	0.94	0.92	0.89	1.00	0.97	0.94	0.72
P_{fp}	1.00	-	-	-	-	-	1.00	0.95	0.00
P_{fp} Low 90% Conf	0.95	-	-	-	-	-	0.95	0.88	-
P_{fp} Upper 90% Conf	1.00	-	-	-	-	-	1.00	1.00	-
P_{ba}	0.05	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.80	0.80	0.80	0.80	0.70	0.95	0.80	0.85	0.30
P_d Low 90% Conf	0.71	0.69	0.67	0.68	0.54	0.75	0.72	0.73	0.08
P_d Upper 90% Conf	0.84	0.86	0.89	0.87	0.82	0.99	0.89	0.94	0.60
P_{fp}	0.75	-	-	-	-	-	0.80	0.70	0.00
P_{fp} Low 90% Conf	0.70	-	-	-	-	-	0.72	0.57	-
P_{fp} Upper 90% Conf	0.81	-	-	-	-	-	0.84	0.81	-
P_{ba}	0.05	-	-	-	-	-	-	-	-

Response Stage Noise Level: 29.00

Recommended Discrimination Stage Threshold: 2.00

Note: The recommended discrimination stage threshold values are provided by the demonstrator.

4.4 EFFICIENCY, REJECTION RATES, AND TYPE CLASSIFICATION

Efficiency and rejection rates are calculated to quantify the discrimination ability at specific points of interest on the ROC curve: (1) at the point where no decrease in P_d is suffered (i.e., the efficiency is by definition equal to one) and (2) at the operator-selected threshold. These values are reported in Table 6.

TABLE 6. EFFICIENCY AND REJECTION RATES

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At operating point	0.91	0.22	0.53
With no loss of P_d	1.00	0.00	0.00

At the demonstrator's recommended setting, the ordnance items that were detected and correctly discriminated were further scored on whether their correct type could be identified (table 7). Correct type examples include "20mm projectile, 105mm HEAT Projectile, and 2.75in Rocket." A list of the standard type declaration required for each ordnance item was provided to demonstrators prior to testing. For example, the standard types for the three example items are 20mmP, 105H, and 2.75in, respectively.

TABLE 7. CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS UXO

Size	Percentage Correct
Small	9.1
Medium	18.8
Large	7.7
Overall	11.3

Note: The demonstrator did not attempt to provide type classification.

4.5 LOCATION ACCURACY

The mean location error and standard deviations are presented in Table 8. These calculations are based on average missed depth for ordnance correctly identified in the discrimination stage. Depths are measured from the closest point of the ordnance to the surface. For the blind grid, only depth errors are calculated, since (X, Y) positions are known to be the centers of each grid square.

TABLE 8. MEAN LOCATION ERROR AND STANDARD DEVIATION

	Mean	Standard Deviation
Depth, m	0.05	0.41

SECTION 5. ON-SITE LABOR COSTS

A standardized estimate for labor costs associated with this effort was calculated as follows: the first person at the test site was designated "supervisor," the second person was designated "data analyst," and the third and following personnel were considered "field support." Standardized hourly labor rates were charged by title: supervisor at $95.00/hour, data analyst at $57.00/hour, and field support at $28.50/hour.

Government representatives monitored on-site activity. All on-site activities were grouped into one of ten categories: initial setup/mobilization, daily setup/stop, calibration, data collection, downtime due to breaks/lunch, downtime due to equipment failure, downtime due to equipment/data checks or maintenance, downtime due to weather, downtime due to demonstration site issue, or demobilization. See Appendix D for the daily activity log. See section 3.4 for a summary of field activities.

The standardized cost estimate associated with the labor needed to perform the field activities is presented in Table 9. Note that calibration time includes time spent in the calibration lanes as well as field calibrations. "Site survey time" includes daily setup/stop time, data collection, breaks/lunch, downtime due to equipment/data checks or maintenance, downtime due to failure, and downtime due to weather.

TABLE 9. ON-SITE LABOR COSTS

	No. of People	Hourly Wage	Hours	Cost
Initial Setup				
Supervisor	1	$95.00	5.56	$528.20
Data analyst	1	57.00	5.56	316.92
Field support	0	28.50	0.00	0.00
Subtotal				**$845.12**
Calibration				
Supervisor	1	$95.00	21.6	$2,052.00
Data analyst	1	57.00	21.6	1,231.20
Field support	2	28.50	21.6	1,231.20
Subtotal				**$4,514.40**
Site Survey				
Supervisor	1	$95.00	26.76	$2,542.20
Data analyst	1	57.00	26.76	1,525.32
Field support	2	28.50	26.76	1,525.32
Subtotal				**$5,592.84**

See notes at end of table.

TABLE 9 (Cont'd)

	No. of People	Hourly Wage	Hours	Cost
Demobilization				
Supervisor	1	$95.00	2.33	$221.35
Data analyst	1	57.00	2.33	132.81
Field support	2	28.50	2.33	132.81
Subtotal				**$486.97**
Total				**$11,439.33**

Notes:
Calibration time includes time spent in the calibration lanes as well as calibration before each data run.

Site Survey time includes daily setup/stop time, collecting data, breaks/lunch, downtime due to system maintenance, failure, and weather.

SECTION 6. COMPARISON OF RESULTS TO BLIND GRID DEMONSTRATION

No comparisons to date.

SECTION 7. APPENDIXES

APPENDIX A. TERMS AND DEFINITIONS

GENERAL DEFINITIONS

Anomaly: Location of a system response deemed to warrant further investigation by the demonstrator for consideration as an emplaced ordnance item.

Detection: An anomaly location that is within R_{halo} of an emplaced ordnance item.

Emplaced Ordnance: An ordnance item buried by the government at a specified location in the test site.

Emplaced Clutter: A clutter item (i.e., non-ordnance item) buried by the government at a specified location in the test site.

R_{halo}: A pre-determined radius about the periphery of an emplaced item (clutter or ordnance) within which a location identified by the demonstrator as being of interest is considered to be a response from that item. If multiple declarations lie within R_{halo} of any item (clutter or ordnance), the declaration with the highest signal output within the R_{halo} will be utilized. For the purpose of this program, a circular halo 0.5 meters in radius will be placed around the center of the object for all clutter and ordnance items less than 0.6 meters in length. When ordnance items are longer than 0.6 meters, the halo becomes an ellipse where the minor axis remains 1 meter and the major axis is equal to the length of the ordnance plus 1 meter.

Small Ordnance: Caliber of ordnance less than or equal to 40 mm (includes 20-mm projectile, 40-mm projectile, submunitions BLU-26, BLU-63, and M42).

Medium Ordnance: Caliber of ordnance greater than 40 mm and less than or equal to 81 mm (includes 57-mm projectile, 60-mm mortar, 2.75 in. Rocket, MK118 Rockeye, 81-mm mortar).

Large Ordnance: Caliber of ordnance greater than 81 mm (includes 105-mm HEAT, 105-mm projectile, 155-mm projectile, 500-pound bomb).

Shallow: Items buried less than 0.3 meter below ground surface.

Medium: Items buried greater than or equal to 0.3 meter and less than 1 meter below ground surface.

Deep: Items buried greater than or equal to 1 meter below ground surface.

Response Stage Noise Level: The level that represents the point below which anomalies are not considered detectable. Demonstrators are required to provide the recommended noise level for the Blind Grid test area.

Discrimination Stage Threshold: The demonstrator selected threshold level that they believe provides optimum performance of the system by retaining all detectable ordnance and rejecting the maximum amount of clutter. This level defines the subset of anomalies the demonstrator would recommend digging based on discrimination.

Binomially Distributed Random Variable: A random variable of the type which has only two possible outcomes, say success and failure, is repeated for n independent trials with the probability p of success and the probability 1-p of failure being the same for each trial. The number of successes x observed in the n trials is an estimate of p and is considered to be a binomially distributed random variable.

RESPONSE AND DISCRIMINATION STAGE DATA

The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the RESPONSE STAGE and DISCRIMINATION STAGE. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of false positive (P_{fp}) and those that do not correspond to any known item, termed background alarms.

The RESPONSE STAGE scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. For the RESPONSE STAGE, the demonstrator provides the scoring committee with the location and signal strength of all anomalies that the demonstrator has deemed sufficient to warrant further investigation and/or processing as potential emplaced ordnance items. This list is generated with minimal processing (e.g., this list will include all signals above the system noise threshold). As such, it represents the most inclusive list of anomalies.

The DISCRIMINATION STAGE evaluates the demonstrator's ability to correctly identify ordnance as such, and to reject clutter. For the same locations as in the RESPONSE STAGE anomaly list, the DISCRIMINATION STAGE list contains the output of the algorithms applied in the discrimination-stage processing. This list is prioritized based on the demonstrator's determination that an anomaly location is likely to contain ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For electronic signal processing, priority ranking is based on algorithm output. For other systems, priority ranking is based on human judgment. The demonstrator also selects the threshold that the demonstrator believes will provide "optimum" system performance, (i.e., that retains all the detected ordnance and rejects the maximum amount of clutter).

Note: The two lists provided by the demonstrator contain identical numbers of potential target locations. They differ only in the priority ranking of the declarations.

RESPONSE STAGE DEFINITIONS

Response Stage Probability of Detection (P_d^{res}): P_d^{res} = (No. of response-stage detections)/(No. of emplaced ordnance in the test site).

Response Stage False Positive (fp^{res}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Response Stage Probability of False Positive (P_{fp}^{res}): P_{fp}^{res} = (No. of response-stage false positives)/(No. of emplaced clutter items).

Response Stage Background Alarm (ba^{res}): An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced ordnance or emplaced clutter item.

Response Stage Probability of Background Alarm (P_{ba}^{res}): Blind Grid only: P_{ba}^{res} = (No. of response-stage background alarms)/(No. of empty grid locations).

Response Stage Background Alarm Rate (BAR^{res}): Open Field only: BAR^{res} = (No. of response-stage background alarms)/(arbitrary constant).

Note that the quantities P_d^{res}, P_{fp}^{res}, P_{ba}^{res}, and BAR^{res} are functions of t^{res}, the threshold applied to the response-stage signal strength. These quantities can therefore be written as $P_d^{res}(t^{res})$, $P_{fp}^{res}(t^{res})$, $P_{ba}^{res}(t^{res})$, and $BAR^{res}(t^{res})$.

DISCRIMINATION STAGE DEFINITIONS

Discrimination: The application of a signal processing algorithm or human judgment to response-stage data that discriminates ordnance from clutter. Discrimination should identify anomalies that the demonstrator has high confidence correspond to ordnance, as well as those that the demonstrator has high confidence correspond to non-ordnance or background returns. The former should be ranked with highest priority and the latter with lowest.

Discrimination Stage Probability of Detection (P_d^{disc}): P_d^{disc} = (No. of discrimination-stage detections)/(No. of emplaced ordnance in the test site).

Discrimination Stage False Positive (fp^{disc}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Discrimination Stage Probability of False Positive (P_{fp}^{disc}): P_{fp}^{disc} = (No. of discrimination stage false positives)/(No. of emplaced clutter items).

Discrimination Stage Background Alarm (ba^{disc}): An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced ordnance or emplaced clutter item.

Discrimination Stage Probability of Background Alarm (P_{ba}^{disc}): P_{ba}^{disc} = (No. of discrimination-stage background alarms)/(No. of empty grid locations).

Discrimination Stage Background Alarm Rate (BAR^{disc}): BAR^{disc} = (No. of discrimination-stage background alarms)/(arbitrary constant).

Note that the quantities P_d^{disc}, P_{fp}^{disc}, P_{ba}^{disc}, and BAR^{disc} are functions of t^{disc}, the threshold applied to the discrimination-stage signal strength. These quantities can therefore be written as $P_d^{disc}(t^{disc})$, $P_{fp}^{disc}(t^{disc})$, $P_{ba}^{disc}(t^{disc})$, and $BAR^{disc}(t^{disc})$.

RECEIVER-OPERATING CHARACERISTIC (ROC) CURVES

ROC curves at both the response and discrimination stages can be constructed based on the above definitions. The ROC curves plot the relationship between P_d versus P_{fp} and P_d versus BAR or P_{ba} as the threshold applied to the signal strength is varied from its minimum (t_{min}) to its maximum (t_{max}) value.[1] Figure A-1 shows how P_d versus P_{fp} and P_d versus BAR are combined into ROC curves. Note that the "res" and "disc" superscripts have been suppressed from all the variables for clarity.

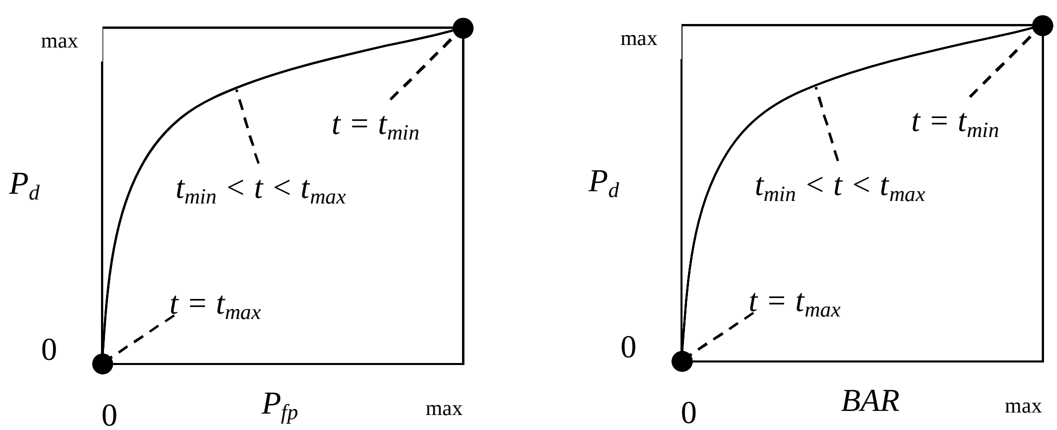

Figure A-1. ROC curves for open field testing. Each curve applies to both the response and discrimination stages.

[1]Strictly speaking, ROC curves plot the P_d versus P_{ba} over a pre-determined and fixed number of detection opportunities (some of the opportunities are located over ordnance and others are located over clutter or blank spots). In an open field scenario, each system suppresses its signal strength reports until some bare-minimum signal response is received by the system. Consequently, the open field ROC curves do not have information from low signal-output locations, and, furthermore, different contractors report their signals over a different set of locations on the ground. These ROC curves are thus not true to the strict definition of ROC curves as defined in textbooks on detection theory. Note, however, that the ROC curves obtained in the Blind Grid test sites are true ROC curves.

METRICS TO CHARACTERIZE THE DISCRIMINATION STAGE

The demonstrator is also scored on efficiency and rejection ratio, which measure the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from non-ordnance items. The efficiency measures the amount of detected ordnance retained by the discrimination, while the rejection ratio measures the fraction of false alarms rejected. Both measures are defined relative to the entire response list, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

Efficiency (E): $E = P_d^{disc}(t^{disc})/P_d^{res}(t_{min}^{res})$; Measures (at a threshold of interest), the degree to which the maximum theoretical detection performance of the sensor system (as determined by the response stage tmin) is preserved after application of discrimination techniques. Efficiency is a number between 0 and 1. An efficiency of 1 implies that all of the ordnance initially detected in the response stage was retained at the specified threshold in the discrimination stage, t^{disc}.

False Positive Rejection Rate (R_{fp}): $R_{fp} = 1 - [P_{fp}^{disc}(t^{disc})/P_{fp}^{res}(t_{min}^{res})]$; Measures (at a threshold of interest), the degree to which the sensor system's false positive performance is improved over the maximum false positive performance (as determined by the response stage tmin). The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all emplaced clutter initially detected in the response stage were correctly rejected at the specified threshold in the discrimination stage.

Background Alarm Rejection Rate (R_{ba}):

Blind Grid: $R_{ba} = 1 - [P_{ba}^{disc}(t^{disc})/P_{ba}^{res}(t_{min}^{res})]$.
Open Field: $R_{ba} = 1 - [BAR^{disc}(t^{disc})/BAR^{res}(t_{min}^{res})])$.

Measures the degree to which the discrimination stage correctly rejects background alarms initially detected in the response stage. The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all background alarms initially detected in the response stage were rejected at the specified threshold in the discrimination stage.

CHI-SQUARE COMPARISON EXPLANATION:

The Chi-square test for differences in probabilities (or 2 x 2 contingency table) is used to analyze two samples drawn from two different populations to see if both populations have the same or different proportions of elements in a certain category. More specifically, two random samples are drawn, one from each population, to test the null hypothesis that the probability of event A (some specified event) is the same for both populations (ref 3).

A 2 x 2 contingency table is used in the Standardized UXO Technology Demonstration Site Program to determine if there is reason to believe that the proportion of ordnance correctly detected/discriminated by demonstrator X’s system is significantly degraded by the more challenging terrain feature introduced. The test statistic of the 2 x 2 contingency table is the

chi-square distribution with one degree of freedom. Since an association between the more challenging terrain feature and relatively degraded performance is sought, a one-sided test is performed. A significance level of 0.05 is chosen which sets a critical decision limit of 2.71 from the chi-square distribution with one degree of freedom. It is a critical decision limit because if the test statistic calculated from the data exceeds this value, the two proportions tested will be considered significantly different. If the test statistic calculated from the data is less than this value, the two proportions tested will be considered not significantly different.

An exception must be applied when either a 0 or 100 percent success rate occurs in the sample data. The chi-square test cannot be used in these instances. Instead, Fischer's test is used and the critical decision limit for one-sided tests is the chosen significance level, which in this case is 0.05. With Fischer's test, if the test statistic is less than the critical value, the proportions are considered to be significantly different.

Standardized UXO Technology Demonstration Site examples, where blind grid results are compared to those from the open field and open field results are compared to those from one of the scenarios, follow. It should be noted that a significant result does not prove a cause and effect relationship exists between the two populations of interest; however, it does serve as a tool to indicate that one data set has experienced a degradation in system performance at a large enough level than can be accounted for merely by chance or random variation. Note also that a result that is not significant indicates that there is not enough evidence to declare that anything more than chance or random variation within the same population is at work between the two data sets being compared.

Demonstrator X achieves the following overall results after surveying each of the three progressively more difficult areas using the same system (results indicate the number of ordnance detected divided by the number of ordnance emplaced):

	Blind Grid	Open Field	Moguls
P_d^{res}	100/100 = 1.0	8/10 = .80	20/33 = .61
P_d^{disc}	80/100 = 0.80	6/10 = .60	8/33 = .24

P_d^{res}: BLIND GRID versus OPEN FIELD. Using the example data above to compare probabilities of detection in the response stage, all 100 ordnance out of 100 emplaced ordnance items were detected in the blind grid while 8 ordnance out of 10 emplaced were detected in the open field. Fischer's test must be used since a 100 percent success rate occurs in the data. Fischer's test uses the four input values to calculate a test statistic of 0.0075 that is compared against the critical value of 0.05. Since the test statistic is less than the critical value, the smaller response stage detection rate (0.80) is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the detection ability of demonstrator X's system seems to have been degraded in the open field relative to results from the blind grid using the same system.

P_d^{disc}: BLIND GRID versus OPEN FIELD. Using the example data above to compare probabilities of detection in the discrimination stage, 80 out of 100 emplaced ordnance items were correctly discriminated as ordnance in blind grid testing while 6 ordnance out of 10 emplaced were correctly discriminated as such in open field-testing. Those four values are used to calculate a test statistic of 1.12. Since the test statistic is less than the critical value of 2.71, the two discrimination stage detection rates are considered to be not significantly different at the 0.05 level of significance.

P_d^{res}: OPEN FIELD versus MOGULS. Using the example data above to compare probabilities of detection in the response stage, 8 out of 10 and 20 out of 33 are used to calculate a test statistic of 0.56. Since the test statistic is less than the critical value of 2.71, the two response stage detection rates are considered to be not significantly different at the 0.05 level of significance.

P_d^{disc}: OPEN FIELD versus MOGULS. Using the example data above to compare probabilities of detection in the discrimination stage, 6 out of 10 and 8 out of 33 are used to calculate a test statistic of 2.98. Since the test statistic is greater than the critical value of 2.71, the smaller discrimination stage detection rate is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the ability of demonstrator X to correctly discriminate seems to have been degraded by the mogul terrain relative to results from the flat open field using the same system.

APPENDIX B. DAILY WEATHER LOGS

Time	Temperature, ^oC	Precipitation, in.
17 May 2006		
0700	27.3	0.00
0800	30.2	0.00
0900	34.4	0.00
1000	36.1	0.00
1100	37.1	0.00
1200	37.9	0.00
1300	38.4	0.00
1400	39.7	0.00
1500	39.8	0.00
1600	39.9	0.00
1700	40.1	0.00
18 May 2006		
0700	27.2	0.00
0800	30.0	0.00
0900	32.1	0.00
1000	33.0	0.00
1100	35.0	0.00
1200	36.3	0.00
1300	37.3	0.00
1400	38.2	0.00
1500	38.7	0.00
1600	38.8	0.00
1700	39.0	0.00
19 May 2006		
0700	26.6	0.00
0800	29.9	0.00
0900	32.1	0.00
1000	33.9	0.00
1100	35.4	0.00
1200	36.6	0.00
1300	38.0	0.00
1400	39.0	0.00
1500	39.3	0.00
1600	39.4	0.00
1700	39.3	0.00

Time	Temperature, °C	Precipitation, in.
22 May 2006		
0700	21.0	0.00
0800	20.6	0.00
0900	16.8	0.00
1000	20.9	0.00
1100	22.0	0.00
1200	23.1	0.00
1300	24.6	0.00
1400	24.9	0.00
1500	26.0	0.00
1600	26.8	0.00
1700	27.2	0.00
23 May 2006		
0700	20.4	0.00
0800	22.1	0.00
0900	24.4	0.00
1000	25.7	0.00
1100	27.3	0.00
1200	28.6	0.00
1300	29.7	0.00
1400	31.1	0.00
1500	32.0	0.00
1600	33.0	0.00
1700	33.3	0.00
24 May 2006		
0700	NA	NA
0800	NA	NA
0900	NA	NA
1000	NA	NA
1100	NA	NA
1200	NA	NA
1300	NA	NA
1400	NA	NA
1500	NA	NA
1600	NA	NA
1700	NA	NA

APPENDIX C.   SOIL MOISTURE

Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Date: 8 May 2006 **Times:** 0800 through 1330			
Calibration Area	0 to 6	1.7	1.6
	6 to 12	2.3	2.3
	12 to 24	3.7	3.8
	24 to 36	3.7	3.7
	36 to 48	4.2	4.2
Mogul Area	0 to 6	1.8	1.7
	6 to 12	3.7	3.7
	12 to 24	3.8	3.8
	24 to 36	4.9	4.8
	36 to 48	5.1	5.2
Desert Extreme Area	0 to 6	4.0	3.8
	6 to 12	3.8	3.7
	12 to 24	3.2	3.2
	24 to 36	4.1	4.0
	36 to 48	4.0	4.0
Date: 9 May 2006 **Times:** 0730 through 1300			
Calibration Area	0 to 6	1.8	1.5
	6 to 12	2.3	2.2
	12 to 24	3.8	3.8
	24 to 36	3.7	3.8
	36 to 48	4.2	4.2
Mogul Area	0 to 6	1.8	1.9
	6 to 12	9.4	3.8
	12 to 24	3.8	3.8
	24 to 36	4.9	4.8
	36 to 48	5.2	5.8
Desert Extreme Area	0 to 6	1.6	1.4
	6 to 12	1.7	1.7
	12 to 24	3.4	3.3
	24 to 36	4.1	4.1
	36 to 48	4.1	4.1

Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Date: 10 May 2006 **Times:** 0700 through 1400			
Calibration Area	0 to 6	1.5	1.4
	6 to 12	2.2	2.3
	12 to 24	3.8	3.8
	24 to 36	3.7	3.7
	36 to 48	4.2	4.1
Mogul Area	0 to 6	1.7	1.9
	6 to 12	3.8	3.8
	12 to 24	3.8	3.8
	24 to 36	4.9	4.9
	36 to 48	5.2	5.2
Desert Extreme Area	0 to 6	6.1	3.8
	6 to 12	3.3	3.8
	12 to 24	3.3	3.3
	24 to 36	4.1	4.1
	36 to 48	4.1	4.1
Date: 11 May 2006 **Times:** 0730 through 1330			
Calibration Area	0 to 6	1.5	1.4
	6 to 12	2.2	2.3
	12 to 24	3.8	3.7
	24 to 36	3.8	3.8
	36 to 48	4.2	4.1
Mogul Area	0 to 6	1.8	1.7
	6 to 12	3.8	3.8
	12 to 24	3.8	3.8
	24 to 36	4.9	4.8
	36 to 48	5.3	5.0
Desert Extreme Area	0 to 6	5.9	5.3
	6 to 12	3.4	3.8
	12 to 24	3.3	3.3
	24 to 36	4.1	4.1
	36 to 48	4.1	4.1

Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Date: 12 May 2006 **Times:** 0730 through 1300			
Calibration Area	0 to 6	1.5	1.3
	6 to 12	2.3	2.3
	12 to 24	3.7	3.7
	24 to 36	3.8	3.8
	36 to 48	4.2	4.1
Mogul Area	0 to 6	1.8	1.8
	6 to 12	3.7	3.8
	12 to 24	3.8	3.8
	24 to 36	4.8	4.6
	36 to 48	5.2	5.0
Desert Extreme Area	0 to 6	6.0	4.9
	6 to 12	3.8	3.7
	12 to 24	3.2	3.2
	24 to 36	4.1	4.1
	36 to 48	4.0	4.1
Date: 15 May 2006 **Times:** 0800 through 1330			
Calibration Area	0 to 6	1.7	1.5
	6 to 12	2.0	2.1
	12 to 24	3.8	3.8
	24 to 36	3.8	3.8
	36 to 48	4.2	4.2
Mogul Area	0 to 6	1.8	1.7
	6 to 12	3.8	3.8
	12 to 24	5.7	3.8
	24 to 36	4.9	4.8
	36 to 48	5.3	5.1
Desert Extreme Area	0 to 6	3.8	4.0
	6 to 12	3.8	3.8
	12 to 24	3.3	3.2
	24 to 36	4.1	4.0
	36 to 48	4.1	4.0

Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Date: 16 May 2006 **Times:** 0730 through 1300			
Calibration Area	0 to 6	1.7	1.6
	6 to 12	2.2	2.2
	12 to 24	3.7	3.8
	24 to 36	3.8	3.8
	36 to 48	4.2	4.2
Mogul Area	0 to 6	1.8	1.8
	6 to 12	3.9	3.7
	12 to 24	3.8	3.8
	24 to 36	4.9	4.8
	36 to 48	5.1	5.0
Desert Extreme Area	0 to 6	3.9	3.7
	6 to 12	3.8	3.8
	12 to 24	3.3	3.2
	24 to 36	4.0	4.0
	36 to 48	4.1	4.0
Date: 17 May 2006 **Times:** 0800 through 1400			
Calibration Area	0 to 6	1.5	1.4
	6 to 12	2.2	2.3
	12 to 24	3.7	3.7
	24 to 36	3.8	3.8
	36 to 48	4.2	4.2
Mogul Area	0 to 6	1.7	1.8
	6 to 12	3.8	3.8
	12 to 24	3.8	3.8
	24 to 36	4.8	4.8
	36 to 48	5.2	5.1
Desert Extreme Area	0 to 6	4.0	3.9
	6 to 12	3.6	3.7
	12 to 24	3.2	3.2
	24 to 36	4.1	4.1
	36 to 48	4.1	4.0

Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Date: 18 May 2006 **Times:** 0730 through 1400			
Calibration Area	0 to 6	1.6	1.4
	6 to 12	2.2	2.3
	12 to 24	3.8	3.7
	24 to 36	3.8	3.8
	36 to 48	4.2	4.1
Mogul Area	0 to 6	1.8	1.8
	6 to 12	2.0	3.8
	12 to 24	3.9	3.8
	24 to 36	4.9	4.8
	36 to 48	5.4	5.1
Desert Extreme Area	0 to 6	0.0	2.1
	6 to 12	3.8	3.7
	12 to 24	3.3	3.2
	24 to 36	4.1	4.0
	36 to 48	4.1	4.0
Date: 19 May 2006 **Times:** 0730 through 1400			
Calibration Area	0 to 6	1.5	1.4
	6 to 12	2.3	2.2
	12 to 24	3.7	3.7
	24 to 36	3.8	3.8
	36 to 48	4.2	4.1
Mogul Area	0 to 6	1.8	1.8
	6 to 12	3.7	3.8
	12 to 24	3.8	3.8
	24 to 36	4.7	4.9
	36 to 48	5.2	6.1
Desert Extreme Area	0 to 6	3.6	3.8
	6 to 12	3.8	3.8
	12 to 24	3.2	3.2
	24 to 36	4.1	4.1
	36 to 48	4.0	4.2

Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Date: 22 May 2006 **Times:** 0730 through 1330			
Calibration Area	0 to 6	1.6	2.1
	6 to 12	2.2	2.4
	12 to 24	3.8	3.9
	24 to 36	3.9	3.9
	36 to 48	4.1	4.1
Mogul Area	0 to 6	2.0	3.1
	6 to 12	3.9	4.3
	12 to 24	3.8	4.0
	24 to 36	4.9	4.8
	36 to 48	5.4	5.2
Desert Extreme Area	0 to 6	3.9	9.1
	6 to 12	3.6	6.2
	12 to 24	3.2	5.4
	24 to 36	4.0	4.7
	36 to 48	4.0	4.2
Date: 23 May 2006 **Times:** 0730 through 1230			
Calibration Area	0 to 6	1.5	1.5
	6 to 12	2.1	2.2
	12 to 24	3.8	3.7
	24 to 36	3.8	3.8
	36 to 48	4.2	4.2
Mogul Area	0 to 6	1.8	1.6
	6 to 12	6.5	5.9
	12 to 24	3.8	3.7
	24 to 36	4.9	4.8
	36 to 48	5.5	5.5
Desert Extreme Area	0 to 6	7.0	6.8
	6 to 12	3.9	3.8
	12 to 24	3.2	3.2
	24 to 36	4.1	4.1
	36 to 48	4.1	4.1

Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Date: 24 May 2006 **Times:** 0730 through NA			
Calibration Area	0 to 6	1.6	NA
	6 to 12	2.1	NA
	12 to 24	3.8	NA
	24 to 36	3.8	NA
	36 to 48	4.2	NA
Mogul Area	0 to 6	1.8	NA
	6 to 12	6.5	NA
	12 to 24	3.8	NA
	24 to 36	4.9	NA
	36 to 48	5.4	NA
Desert Extreme Area	0 to 6	9.7	NA
	6 to 12	3.8	NA
	12 to 24	3.3	NA
	24 to 36	4.1	NA
	36 to 48	4.1	NA

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
17 May	2	CALIBRATION LANES	0703	1237	334	INITIAL SETUP	Assembling the ALL TEM system	NA	NA	NA	Slightly Cloudy	Warm
17 May	2	CALIBRATION LANES	1237	1303	26	BREAK/LUNCH	Lunch	NA	NA	NA	Sunny	Hot
17 May	2	CALIBRATION LANES	1303	1440	97	INITIAL SETUP	Continued to assemble the ALL TEM system	NA	NA	NA	Sunny	Hot
17 May	4	CALIBRATION LANES	1440	1606	86	INITIAL SETUP	Continued to assemble the ALL TEM system; incomplete	NA	NA	NA	Sunny	Hot
17 May	4	CALIBRATION LANES	1608	1625	17	DAILY START, STOP	Breakdown end of day	NA	NA	NA	Sunny	Hot
18 May	4	CALIBRATION LANES	0635	0842	127	DAILY START, STOP	Setup of equipment and calibrating the system	NA	NA	NA	Sunny	Cool
18 May	4	CALIBRATION LANES	0842	1245	243	COLLECTING DATA		GPS	NA	Linear	Sunny	Warm
18 May	4	CALIBRATION LANES	1245	1445	120	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	Downloading data	NA	NA	NA	Sunny	Hot
18 May	4	CALIBRATION LANES	1445	1501	16	DAILY START, STOP	Breakdown end of day	NA	NA	NA	Sunny	Hot
19 May	4	BLIND TEST GRID	0645	0743	58	DAILY START, STOP	Setup of equipment and calibrating the system	NA	NA	NA	Sunny	Cool
19 May	4	BLIND TEST GRID	0743	1242	299	COLLECTING DATA	Ran blind grid north to south, west to east using the towed ALL TEM system; completed	GPS	NA	Linear	Sunny	Hot

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
19 May	4	BLIND TEST GRID	1242	1408	86	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	Downloading and inspecting the data; data are good	NA	NA	NA	Sunny	Hot
19 May	4	BLIND TEST GRID	1408	1613	125	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	Troubleshooting hardware noise, reporting a little more noise than desired	NA	NA	NA	Sunny	Hot
19 May	4	BLIND TEST GRID	1613	1645	32	DAILY START, STOP	Breakdown end of day	NA	NA	NA	Sunny	Hot
22 May	4	BLIND TEST GRID	0700	0714	14	DAILY START, STOP	Setup of equipment	NA	NA	NA	Windy/ Cloudy	Cold
22 May	4	BLIND TEST GRID	0714	1338	384	DOWNTIME DUE TO EQUIPMENT FAILURE	Replacing system's computer system due to data download being slow; computer system had shifted and bounced around a little during transport to YPG via company-owned vehicle, thus affecting the speed the data downloads; no previous problem until now noted	NA	NA	NA	Raining	Cold

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
22 May	4	BLIND TEST GRID	1338	1446	68	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	Calibrating system due to the computer change and to verify if the noise level had changed; the noise level remained; continued to troubleshoot	GPS	NA	Linear	Windy/ Cloudy	Cool
22 May	4	BLIND TEST GRID	1446	1547	61	DOWNTIME DUE TO EQUIPMENT FAILURE	Troubleshooting the system capacitors; replaced the system amplifier and added a ground to the circuit board in hopes of eliminating the noise	NA	NA	NA	Windy/ Cloudy	Cool
22 May	4	BLIND TEST GRID	1547	1627	40	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	Calibrating the system again and inspecting the noise level to see if the level decreased; no change	GPS	NA	Linear	Sunny	Warm
22 May	4	BLIND TEST GRID	1627	1655	28	DAILY START, STOP	Breakdown end of day	NA	NA	NA	Sunny	Warm
23 May	4	BLIND TEST GRID	0630	0643	13	DAILY START, STOP	Setup of equipment	NA	NA	NA	Sunny	Cool

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

Date	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
23 May	4	BLIND TEST GRID	0643	0724	41	DOWNTIME DUE TO EQUIPMENT FAILURE	Replacing the triangle wave control circuit board for the system in an attempt to eliminate the noise	NA	NA	NA	Sunny	Cool
23 May	4	BLIND TEST GRID	0724	0819	55	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	Calibrating the system again and inspecting the noise level to see if the level decreased; level decreased	NA	NA	NA	Sunny	Cool
23 May	4	BLIND TEST GRID	0819	1251	272	COLLECTING DATA	Running the blind grid north to south, west to east using the towed ALL TEM system with the changes made to the system; completed	GPS	NA	Linear	Sunny	Warm
23 May	4	BLIND TEST GRID	1251	1321	30	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	Downloading and inspecting the data; data are good	NA	NA	NA	Sunny	Warm
23 May	4	CALIBRATION LANES	1321	1626	185	COLLECTING DATA	Running the calibration grid south to north, west to east using the towed ALL TEM system with the changes made to the system; completed	GPS	NA	Linear	Sunny	Warm

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
23 May	4	CALIBRATION LANES	1626	1700	34	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	Downloading data	NA	NA	NA	Sunny	Warm
23 May	4	CALIBRATION LANES	1700	1730	30	DAILY START, STOP	Breakdown end of day	NA	NA	NA	Sunny	Warm
24 May	4	CALIBRATION LANES	0630	0646	16	DAILY START, STOP	Setup of equipment; incomplete	NA	NA	NA	Sunny	Cool
24 May	4	CALIBRATION LANES	0646	0657	11	DOWNTIME DUE TO EQUIPMENT FAILURE	Repairing the flat front wheel of the system	NA	NA	NA	Sunny	Cool
24 May	4	CALIBRATION LANES	0657	0741	44	DAILY START, STOP	Continued to set up equipment; completed	NA	NA	NA	Sunny	Cool
24 May	4	CALIBRATION LANES	0741	0753	12	DOWNTIME DUE TO EQUIPMENT FAILURE	Reported one intermittent cable on one of the seven digitizer channels, replaced cable; replaced the serial port out cable for the GPS unit; system not receiving GPS information	NA	NA	NA	Sunny	Cool
24 May	4	CALIBRATION LANES	0753	0816	23	DAILY START, STOP	Continued to set up and calibrate equipment; completed	NA	NA	NA	Sunny	Cool

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
24 May	4	CALIBRATION LANES	0816	0843	27	COLLECTING DATA	Performing diagonal runs over a portion of the calibration grid; incomplete	GPS	NA	Linear	Sunny	Warm
24 May	4	CALIBRATION LANES	0843	0904	21	BREAK/LUNCH	Break Note: Craig Moulton lost his footing on the grade just off of the calibration grid; slipped and hit his head on the system; sustained a cut (about 3 in.) on the top of his head; cut was cleaned and bandaged; he did not require any further medical attention	NA	NA	NA	Sunny	Warm
24 May	4	CALIBRATION LANES	0904	0954	50	COLLECTING DATA	Continued diagonal runs over a portion of the calibration grid; completed	GPS	NA	Linear	Sunny	Warm

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

Date, 2006	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
24 May	4	CALIBRATION LANES	0954	1246	172	COLLECTING DATA	Performing a high-density grid (cued mode) over selected targets on the calibration grid; completed	GPS	NA	Linear	Sunny	Hot
24 May	4	CALIBRATION LANES	1246	1311	25	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/ CHECK	Downloading data	NA	NA	NA	Sunny	Hot
24 May	4	CALIBRATION LANES	1311	1531	140	DEMOBILIZATION	Disassembling the system and packing up equipment	NA	NA	NA	Sunny	Hot

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

APPENDIX E. REFERENCES

1. Standardized UXO Technology Demonstration Site Handbook, DTC Project No. 8-CO-160-000-473, Report No. ATC-8349, March 2002.

2. Aberdeen Proving Ground Soil Survey Report, October 1998.

3. Data Summary, UXO Standardized Test Site: APG Soils Description, May 2002.

4. Yuma Proving Ground Soil Survey Report, May 2003.

5. Practical Nonparametric Statistics, W.J. Conover, John Wiley & Sons, 1980, pages 144 through 151.

APPENDIX F. ABBREVIATIONS

APG	=	U.S. Army Aberdeen Proving Ground
ASCII	=	American Standard Code for Information Interchange
ATC	=	U.S. Army Aberdeen Test Center
EM	=	electromagnetic
ERDC	=	U.S. Army Corps of Engineers Engineering Research and Development Center
ESTCP	=	Environmental Security Technology Certification Program
EQT	=	Army Environmental Quality Technology Program
GPS	=	Global Positioning System
HEAT	=	high-explosive antitank
HFS	=	high frequency sounder
JPG	=	Jefferson Proving Ground
LLC	=	Limited Liability Company
MEC	=	munitions and explosives of concern
NOAA	=	National Oceanic and Atmospheric Administration
PC	=	personal computer
POC	=	point of contact
QA	=	quality assurance
QC	=	quality control
ROC	=	receiver operating characteristic
RX	=	receiver
SERDP	=	Strategic Environmental Research and Development Program
TMGS	=	Tensor Magnetic Gradiometer System
TX	=	transmitter
USAEC	=	U.S. Army Environmental Command
USGS	=	U.S. Geological Survey
UXO	=	unexploded ordnance
VETEM	=	very early time electromagnetic
YPG	=	U.S. Army Yuma Proving Ground

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